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The Effect of Rations Excessively High and Extremely Low in Protein Content on Dairy Cows

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THE EFFECT OF RATIONS EXCESSIVELY HIGH AND EXTREMELY LOW IN PROTEIN CONTENT ON DAIRY COWS

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The proportion of protein in the ration of the dairy cow has long been recognized as one of the more important considerations in the proper feeding of such animals. In addition to a comparatively constant amount of protein needed for body maintenance, the efficient ration must supply an adequate amount to support milk production which varies widely during the course of lactation, the protein requirement being affected by the quality as well as the quantity of milk produced. At the height of production the energy requirement and especially the protein requirement is often several times that of the same cow when dry, though the bulk of the ration cannot be correspondingly increased.

All protein produced in the milk must eventually be supplied in the food and some margin of excess is probably needed though the authorities differ widely as to the necessary amount of this surplus requirement.

There exists the idea supported to some extent by the literature that dire consequences to the cow may result from the long continued use either of too much or too little protein in the dairy ration, while at the same time the idea has been widely held that additional protein above the actual requirement is an effective stimulus to liberal milk production.

In connection with the problem of devising a ration which is adequate or ideal from the physiological standpoint there is also the consideration that feeds which supply large amounts of protein are normally far more costly than equally desirable feeds of lower protein content. Thus while it is important that sufficient protein be supplied to support liberal production, it is also important, at least from an

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economic standpoint, that large excesses of protein above the actual needs be avoided. Constant attention to this problem is demanded of the efficient dairyman. The effect of the continuous long time feeding of rations extremely high (nutritive ratio 1:2) or extremely low (nutritive ratio 1:13) in protein content on the welfare and production of dairy cows has, however, received comparatively little attention from investigators of dairy problems.

REVIEW OF LITERATURE

In previous publications the writer has reported data regarding the effects of the long continued feeding of rations ranging in nutritive ratio from 1:4 to 1:9 between the digestible protein and remaining digestible nutrients (20) (23). The earlier literature of the subject is reviewed in these publications. The net effect of the experimental feeding as there reported was much less striking than had been anticipated. The animals adjusted themselves well to the ration supplied, remained in good condition and maintained reasonably good production which was not strikingly different between the contrasted groups.

Other investigators reporting at about the same time arrived at similar conclusions (5) (13). Our investigations were continued, using rations still more extreme with respect to protein content. A portion of the results are herewith presented. Some of the results with respect to the composition of the milk and butterfat have been presented previously (23) while the results dealing with the composition of the blood, urine, saliva and bile will follow.

Cary (6) reported decidedly unfavorable results as to production and condition of the cow for the use of a low protein ration for a single lactation period. The ration however contained considerably more protein in relation to live weight and milk production than the 1:13 ration used in this experiment. The rations used by Cary are not presented in detail however so we are unable to make a critical comparison.

EXPERIMENTAL PROCEDURE

Experimental Animals

The animals used in this experiment were purebred cows of the Holstein-Friesian breed. Some of them were started on the experimental feeding as well-grown heifers; others during either the first or second lactation period, and continued thereon indefinitely. In certain sections of the work, however, some data are included from older cows which had been receiving the experimental rations for shorter lengths of time.

The cows were stall-fed throughout the year, but in suitable weather were kept outdoors together with other experimental cows, in a lot devoid of vegetation. They were bedded with wood shavings and had ample supplies of water and common salt. The cows were fed and milked twice daily. Records of the live weight of the cows, the feed consumption, and the milk and butterfat production were regularly taken.

Feeding

The rations compared as to their effects in this experiment were planned to give an extreme degree of difference with respect to protein content; but at the same time to be as nearly normal as possible in all other respects. One ration had a nutritive ratio between the digestible protein and the remaining digestible nutrients of 1:2. It supplied a great excess of protein over the needs of the cow, usually several times as much as called for by any of the recognized feeding standards. The other ration was very deficient in protein. It had a nutritive ratio of 1:13 and supplied much less protein than is called for by even the lowest of the recognized feeding standards. As much of each of these rations was fed as the cows would consume regularly without excessive waste. The prescribed proportion between the different ingredients of the ration was, however, carefully maintained. The amount of dry matter eaten on these respective rations has been quite similar but has seemed to average about 1 pound higher per day for the high-protein ration.

In general, the feeds used were of good quality. A considerable variety of feeds rather than only a few feeds was used to minimize any possible specific effects or deficiencies of individual feeds. In planning these experimental rations use was made of the average composition of the feeds in terms of digestible crude protein and total digestible nutrients as given in the tables published by Henry and Morrison (11) and Morrison (16). The feeds used have been analyzed from time to time, particularly with respect to their protein content and checked against the average values, as shown in Table 1. In at least three instances, viz., timothy hay, corn silage, and corn gluten meal analyses are given in the 20th Edition of Feeds and Feeding which come considerably closer to our own analysis than those found in the older edition. Marked departures of the analyses from the average figures have been few, however. For the most part, these have tended to offset one another but the net result has usually been in the direction of intensifying the planned difference between the rations. In the case of certain

TABLE 1.—Analysis of Feeds Used
100 pounds of feed contain pounds

	Total protein found	Number of analyses made	Average composition* protein		Total† digestible nutrients
			Total	Digest	
Timothy hay	5.18	8	6.2	3.0	48.5
Corn silage	2.62	8	2.1	1.1	17.7
Alfalfa hay	13.29	9	14.4	10.2	50.6
Cane molasses	1.63	3	3.2	1.0	59.5
Ground corn	9.08	7	9.6	7.1	81.7
Ground oats	12.68	7	12.4	9.7	70.4
Wheat bran	15.64	6	15.7	12.2	59.6
Corn starch	.48	3			
Dried beet pulp	8.22	3	8.9	4.6	71.6
Cottonseed meal	39.95	4	39.8	33.4	75.5
Linseed oilmeal	36.93	6	33.9	30.2	77.9
Corn gluten meal	43.92	3	44.4	37.7	81.4
Peanut oilmeal	41.0	3	44.8	40.3	83.5
Soybean oilmeal	45.60	3	43.2	39.7	84.5
Blood meal	82.08	3	82.2	70.7	75.9
Wheat gluten	80.39	5			

*Feeds and Feeding (11) (16).

†Total digestible nutrients = digestible protein plus digestible carbohydrate plus 2.25 × digestible fat (16).

feeds whose composition and digestibility are not given in the average tables our own analyses were used in connection with the digestion coefficients for a similar feed.

Average digestion coefficients have been adhered to in spite of the fact that in some of our own previously-publised work (19) (21) under quite similar conditions the observed digestibility of the mixed ration was found to be considerably less than the digestibility as calculated by the use of the average coefficients. Eckles (7) has shown that digestion is apparently less complete in case of the lactating cow than in case of the same animals when dry. Eckles found that the digestibility figures in case of the dry cows in his experiment agreed closely with the published figures, which have been mostly derived from work with steers at or near the maintenance level.

TABLE 2.—Typical Ration *, †, Nutritive Ratio, 1:2

Alfalfa hay	16 parts by weight
Corn silage	16 parts by weight
Grain mixture	12 parts by weight

Composition of Grain Mixture:

	lb.
Cottonseed meal	100
Linseed oilmeal	100
Peanut oilmeal	100
Soybean oilmeal	100
Corn gluten meal	100
Wheat bran	100
Wheat gluten	150
Blood meal	150

*Salt equal to one percent of the grain mixture added.

†Digestible crude protein content of entire ration is about 20 percent (Air-dry basis).

Specimen rations of each type are shown in Tables 2 and 3.

Rations agreeing closely in composition to those shown in Tables 2 and 3 were in successful experimental use for several years and were on the whole well relished and taken by the cows. Considerable difficulty was encountered at first, however, in finding rations suitable both to the cows and to the experiment.

TABLE 3.—Typical Daily Ration *, †, Nutrtitive Ratio, 1:13

Timothy hay	10 parts by weight
Corn silage	30 parts by weight
Cane molasses (on the hay)	1.5 parts by weight
Grain mixture	10 parts by weight

Composition of Grain Mixture:

	Percent
Ground corn	66 2/3
Ground oats	11 1/9
Wheat bran	11 1/9
Corn starch	11 1/9

*Salt equal to one percent of the grain mixture added.

†Two ounces of bone meal was fed daily in connection with this ration to guard against probable calcium and phosphorus deficiencies.

EFFECT OF RATIONS ON THE CONDITION OF THE COWS AND ON PRODUCTION

Table 4 and 5 are presented to show approximately the degree of abnormality of the experimental rations and their effect on the level of milk production, while Table 6 and 7 are introduced to show something

TABLE 4.—Protein Requirement and Supply; Eight Lactation Periods on 1:2 Ration

Cow Numbers	192	146	154	154
Lactation period	3d	8th	8th	9th
	POUNDS			
Digest. crude protein supplied	2217	2274	2170	2215
D.C.P. required for maintenance	281	281	306	306
Protein contained in milk*	300	317	259	280
Protein produced plus maintenance	581	598	565	586
Protein in excess of above amounts	1636	1676	1605	1629
Protein supply above maintenance per pound protein production	6.45	6.28	6.09	6.82
Production, 4% milk	9121	9632	7860	8509
	(2)†	(4)	(4)	(4)
Previous production, 4% milk	9460	9767	8953	8953
Cow Numbers	292	329	332	332
Lactation period	3d	1st	1st	2d
	POUNDS			
Digest. crude protein supplied	2378	1883	1948	2127
D.C.P. required for maintenance	306	281	281	281
Protein contained in milk*	365	277	252	226
Protein produced plus maintenance	671	558	533	507
Protein in excess of above amounts	1707	1325	1415	1620
Protein supply above maintenance per pound protein production	5.68	5.78	6.61	8.16
Production, 4% milk	11098	8424	7654	6855
	(1)			
Previous production, 4% milk	11507			

*Calculated from the author's formula (22) $P = 2.78 + .42 \ (F-2.78)$ or $P = .42 F. + 1.61$.

†Figures in parenthesis indicate the number of previous lactations used in calculating average.

TABLE 5.—Protein Requirement and Supply; Eight Lactation Periods on 1:13 Ration

Cow Numbers	293	293	301	301
Lactation period	2d	3d	3d	4th
Length lactation and dry period, days	365*	365*	392	395
	POUNDS			
Remarks—				
Digest. crude protein supplied	447	402	363	378
D. C. P. required for maintenance	281	281	250	260
Protein contained in milk †	201	171	147	175
Protein produced plus maintenance	482	452	397	435
Excess of above over supply	35	50	34	57
Protein supply per pound protein production above maintenance	.82	.71	.77	.67
Production of 4% milk	6123	5181	4459	5307
Production during 1st lactation period, normal feeding, 4% milk	7976		7076	

Cow Numbers	301	301	362	362
Lactation period	6th	7th	4th	5th
Length lactation and dry period, days	381	373	385	561
	POUNDS			
Remarks—				
Digest. crude protein supplied	455	461	422	579
D. C. P. required for maintenance	315	287	323	432
Protein contained in milk †	219	247	231	299
Protein produced plus maintenance	534	534	534	731
Excess of above over supply	79	73	132	152
Protein supply per pound protein production above maintenance	.64	.70	.43	.49
Production of 4% milk	6647	7506	7034	9100
Production during 1st lactation period, normal feeding, 4% milk	7076		8654	

*First 365 days of a prolonged lactation.

†Protein percentage calculated by the writer's formula (22) = $P = .42F + 1.61$ Where P=protein percentage and F=fat percentage in normal milk.

of the effects of these rations on the live weight of the cows. The difference of approximately 200 pounds in the average live weight of the two groups may be partly attributed to the rations since two of the cows in the high protein-fed group were apparently of larger frame than the two cows furnishing the data on the low-protein ration. Part of this difference may also have been due to the fact that there were more abnormally long lactation periods due to delayed and uncertain breeding in the high protein group than in the other.

Perhaps the most noticeable differences in the live weight records of the two groups is the extent of the live weight decline occurring in the early part of the lactation period. Except for the loss of about 200 pounds at calving time the live weight of the high-protein group appears to have been nearly uniform except for a corresponding gain near the close of lactation and during the following dry period. The low protein group continued to lose weight during the period of heaviest production until the fifth month when there was a slow and gradual increase until the end of the period. It was at about the fourth to the sixth month of lactation that the greatest difference in condition of the two lots of cows was evident. The high-protein group being always in what would

TABLE 6.—Live Weight Variations; Extreme Low Protein Ration

Number of Cows	Time of Weighing	Weight, pounds	
		Total	Average
7	before calving	8858	1265
7	1st month after calving	7465	1065
6	2nd month after calving	6079	1013
6	3rd month after calving	5930	988
6	4th month after calving	5888	981
6	5th month after calving	5792	965
6	6th month after calving	5852	975
6	7th month after calving	5912	985
6	8th month after calving	6011	1002
6	9th month after calving	6063	1011
6	10th month after calving	6142	1024
6	11th month after calving	6308	1051
6	12th month after calving	6595	1099
5	13th month after calving	5734	1147
6	Last month before calving	7606	1268

TABLE 7.—Live Weight Variations; Extreme High Protein Ration

Number of Cows	Time of Weighing	Weight, pounds	
		Total	Average
9	before calving	12730	1414
9	1st month after calving	10696	1188
9	2nd month after calving	10589	1176
9	3rd month after calving	10690	1188
9	4th month after calving	10487	1165
9	5th month after calving	10596	1177
8	6th month after calving	9736	1217
8	7th month after calving	9447	1181
8	8th month after calving	9418	1177
8	9th month after calving	9654	1207
7	10th month after calving	8547	1221
7	11th month after calving	8649	1236
7	12th month after calving	8832	1262
7	13th month after calving	9017	1288
7	14th month after calving	9272	1325
8	Last month before calving	11376	1421

ordinarily be considered a good condition of flesh. The cows of the low-protein group on the other hand, were generally decidedly thin at this time. The extreme fluctuation of live weight for this group was at least 50 pounds greater than with the other group and the initial condition at calving time while reasonably satisfactory was not nearly as high as in the other group. Hills and associates found little or no change in body condition of dairy cows accompanying the long continued use of rations varying widely in protein content. The rate of production in their experiments, however, was not very high and the range of protein content was far less than in the present experiment.

Concerning the milk production as shown in Tables 4 and 5, that for the high-protein group was somewhat less than the production which presumably might have been expected from the same cows on ordinary feeding, as judged by the previous production of some of them. The production on the exeremely low protein feeding was decidedly less than had been made by some of the group as first-calf heifers, and was probably not much more than half what these same cows would have made at like age on ordinary good feeding.

SIGNIFICANCE OF DATA WITH RESPECT TO MINIMUM PROTEIN REQUIREMENT

In Tables 8 and 9 are presented some interesting and suggestive data concerning the performance of cow 301 on the 1:13 ratio for five full successive lactation periods. Table 8 shows the breeding and calving record of this cow to have been remarkably regular and the calves of good birth-weight, and normal appearance. The live weight was practically maintained from year to year, though the cow did not take on additional weight as is common for liberally fed cows of this age.

Table 9 gives data regarding the calculated requirement and supply of protein for cow 301 during this 5½-year period. If the conventional maintenance requirement is deducted from the total supply of protein fed, the amount remaining for all other uses is only approximately two-thirds of the amount of protein actually produced in the milk. If on the other hand, the actual production of milk protein is deducted from the total supply, only .66 pound daily remain for maintenance of a 1200-pound cow, or .55 per 1000 pounds liveweight. If only the milking period proper is considered the maintenance was accomplished on less than .5 pound per day. Other workers in recent years have observed similar low values for the minimum maintenance requirement. For practical purposes, however, we have no desire to displace the conventional allowance of .6 pound. These data also apparently mean that the digestible portion of feed protein may be almost quantitatively converted into milk protein. This has been a matter of much uncertainty in the past, which has resulted in keeping

TABLE 8.—Production Record for Cow 301; Extreme Low Protein, 1:13 Ration

Lactation No.	Maximum live weight observed	Production 4% milk	Days in milk	Dry period, Days	Weight next calf
3rd	1225	4459	324	69	100
4th	1168	5307	338	57	112
5th	1385	6266	344	58	110
6th	1307	6647	336	56	110
7th	1257	7506	321	52	77
Average	1268	6037	332	58	102

recommendations regarding the protein feeding of dairy cows at unnecessarily high levels. Incidentally, attention should be called at this point to the fact that the digestibility of protein in low-protein rations such as this is little or no greater than in the case of rations containing an abundance of protein as shown by Perkins and Monroe (19). In fact, Ellett and Holdaway (9) found considerably lower digestibility coefficients in the case of low protein or high energy rations, while that of their high-protein rations was unaffected by the extra protein. The condition under which their work was done differed greatly, however, from those in our experiments. This was further discussed in the articles first cited.

One group of feeding authorities headed by Dr. H. P. Armsby practically ignored the non-protein or so-called "amid nitrogen" which is included in the group known as crude protein. They have followed a feeding standard based on what they term as "true protein". Armsby (2), Putney and Armsby (18) have published tables giving the composition of the common feeding stuffs in terms of "true protein" and "amid nitrogen".

It is interesting to note that on the basis of Armsby's average figures 22 percent of the nitrogen in the low protein (1:13) ration was in the form of amids rather than true protein. This proportion is higher than found in the average ration; so that from the true protein standpoint this ration was still more deficient in protein than shown in the tables presented. Watson and Ferguson (29) have shown that the large amount of nitrogen in grass silage which is broken down beyond the true protein stage is valuable as protein in the dairy ration. Practical observation in many cases leads to a like conclusion.

TABLE 9.—Protein Requirement and Supply, Cow 301, 1:13 Ration, Average of Five Lactations

Average lactation, including dry period	391	days
Average digestible crude protein in feed	459	pounds
Maintenance requirement, (Haecker Standard, 1200 lb.)	328	pounds
Remaining for other uses	131	pounds
Protein produced in milk	198	pounds
Protein above maintenance for each pound protein in milk	0.66	pound
Average production, 4% milk	6,037	pounds

Steiner (28) has also shown that the apparent digestibility of the crude protein of A.I.V. and some other grass silages with sheep was considerably greater than the digestibility of the true protein in the same materials which indicates greater digestibility for the non-protein nitrogen. He also found there was only the normal decline in milk production of dairy cows when such silages were made to largely replace the usual ration.

Morris and Wright (15) and others have apparently shown marked differences in the efficiency of the proteins for maintenance in several of the common dairy feeds. The feeds used in the low-protein section of this experiment were not considered but evidently must be of relatively high efficiency.

EFFECT ON BREEDING AND PROGENY

One of the chief points of interest to the dairyman regarding the use of such rations lies in the effect they may have on the ability of the cow to conceive regularly and produce normal young. Ordinarily, it is desired that the cow should freshen regularly at intervals of 12 to 14 months. The extensive use of high-protein rations has been popularly accused of causing delayed breeding and sterility. In Table 10 are presented data regarding the length of the intervals between calvings of the cows in this experiment. Many of these intervals are seen to be longer than desirable. In such cases repeated breeding was usually required.

TABLE 10.—Intervals Between Calvings, Days

	High Protein Feeding					
Lactation	1	2	3	4	5	6
Cow 292	840	529	Sold sterile			
Cow 329	743	413	410*			
Cow 332	578	428	446	545	347 A	
Cow 414	518	448	518*			
	Low Protein Feeding					
Lactation	1	2	3	4	5	6
Cow 264	781	Sold sterile				
Cow 293	793	565	Sold sterile			
Cow 301	393	395	401	392	373	454 A
Cow 362		385	472	Sold sterile		

*Pregnant when slaughtered
A Sold sterile

Treatments by the veterinarian to bring on the heat-period or to make conditions more favorable for conception were necessary in many such cases. The cows sold as sterile were declared to be hopeless cases by the veterinarian. In two cases, however, animals so classified were found on slaughter to be in an early stage of pregnancy.

Delayed breeding and sterility have been troublesome factors in both groups of cows. Since the same trouble has prevailed to a considerable extent in the herd at large, however, and Brucellosis has been present in the herd the blame cannot be definitely placed on the conditions of this experiment. Considering the small number of animals involved the results regarding delayed breeding and sterility have been too variable to permit of generalization. The calves produced by both groups of cows have apparently been normal and well developed.

Evans and Risley (10), Polvogt, McCollum, and Simmonds, (26) and Blatherwick and Medlar (4) and others have reported kidney injury to rats apparently due to high protein content in the diets, while Addis, MacKay and MacKay (1); Osborn, Mendel, Edwards and Winternitz (17) and others have failed to find any other effect than hypertrophy from the long continued use of high-protein diets. The latter workers suggest that some of the injurious effects observed by the others were probably due to other deficiencies in the diets. Osborn **et al.** reported the use of diets in which two-thirds of the energy was supplied in the form of protein. So great a concentration of protein in the diet would scarcely be possible in the case of the dairy cow since none of the roughage constituents which ordinarily make up a large part of the cow's ration contains more than 14 to 18 percent protein and only a few of the usual ingredients of the grain ration contain more than 40 percent total protein. Moreover, as we have shown in previous work, a great preponderance of grain in the cow's ration is likely to bring about symptoms akin to those observed in acidosis. Ragsdale and McIntyre, however, reported the successful use of an exclusively grain ration.

In the present experiment we have found it necessary to include wheat gluten and blood meal, neither of which are commonly used in dairy rations, to bring the digestible protein content to the 33 1/3 percent level, as has been done in the 1:2, of high-protein ration.

No evidence of kidney difficulty was noted in any of the cows in this experiment, and macroscopic examination of the internal organs at the time of slaughter revealed no abnormalities which seemed at all relevant, although no histological studies were made.

REQUIREMENTS AND SUPPLY OF CALCIUM AND PHOSPHORUS

It was recognized at the beginning of this experiment even in the absence of definite figures for the calcium and phosphorus requirement of dairy cows that the narrow ration with more than 100 grams of calcium and 150 garms of phosphorus probably contained a considerable excess of both these minerals. While the wide, or low protein ration, was thought possibly to be deficient in both of them; as a corrective of this situation each animal on the low-protein ration was fed 2 ounces of bone meal daily. According to the Morrison tables (16) this should approximately be 18.5 grams of calcium and 8.5 grams of phosphorus. The feeds of the low protein ration probably supplied between 27 and 28 grams of calcium and between 31 and 32 grams of phosphorus. The total ration including the bone meal and water thus supplied about 50 grams of calcium and 40 grams of phosphorus.

According to the phosphorus standard announced by Huffman **et al.** (14) this should be sufficient for the production of about forty pounds of milk per day in addition to maintenance, which is far in excess of the average production of the low protein cows. There was then probably no phosphorus deficiency.

The calcium requirement cannot be quite so definitely stated but in general it may be said that the apparent calcium deficiencies of dairy cows which have been shown and widely discussed in many balance experiments have seemingly been due more to the inability of the cow to assimilate sufficient quantities of calcium than to a lack of calcium in the ration. Ellenberger, Newlander, and Jones (8) moreover, have shown calcium and phosphorus equilibrium over the entire lactation periods on rations containing no more calcium than the low-protein ration here described. The cows used in their studies were producing liberally at the time. When mineral supplements were fed, storage of both elements was achieved in all cases over full lactation periods.

The calcium content of the low protein ration in the present experiment is several times the calcium content of the milk produced and the ration including the bone meal supplied an amount of calcium considerably in excess of the amount arrived at by Morrison (16) as a suitable minimum amount, 0.2 percent of dry matter content of the ration. There were no evidences of calcium deficiency such as described by Becker **et al.** (3) so the ration may be considered normal in this respect. Also the calcium-phosphorus ratio was within the range which is considered desirable.

A study of these rations for the presence of the various vitamins according to the values as given by Morrison (16), as far as this information is available, will show that both ratios are reasonably well supplied with the vitamins known to be essential in dairy rations.

GENERAL DISCUSSION

It is not thought that the experimental rations herein described are in any sense practical dairy rations. In case of the high protein ration the grain mixture with the single exception of wheat bran consisted solely of high protein concentrate. Two of the ingredients, blood meal and wheat gluten, which consist almost entirely of protein are seldom used as dairy feeds. Corn silage an excellent and economical dairy feed has been limited to merely a token allowance because of its low protein content. Corn and oats the basis of most economical grain mixtures have been omitted for the same reason. Alfalfa hay, on the other hand, would be difficult to improve upon being the highest in protein of the common roughages. The ration as it stands would be too expensive for use under practical conditions and probably less efficient than many cheaper and more commonplace rations which could be more readily provided.

In the low protein ration we have gone to the opposite extreme and avoided protein in the feeds wherever possible. Timothy hay, about the lowest in protein content of the commonly fed hays, has been used. It was treated with molasses which is a very low protein product to improve its palatability. Corn silage was fed liberally because it was low in protein. Two-thirds of the grain mixture consisted of ground corn the lowest in protein of the common grains, and a third of the remainder consisted of corn starch, an almost protein free high energy product. Oats and wheat bran were present for the sake of variety but in only small amounts. Here again we have gone out of the way and far beyond practical limits to obtain a low protein experimental ration.

While seeking abnormal proportions of protein in the two rations every effort has been made to keep them normal in other respects. In both rations there was about a normal balance between roughage and concentrates, an important consideration since the writer has shown the development of the symptoms of acidosis when abnormally large amounts of grain were fed. Ragsdale and McIntyre (27), however, report success with the use of an exclusive grain ration. The minerals, calcium and phosphorus, often thought to be deficient in dairy rations are shown to be present in those experimental rations in substantially adequate amounts. The rations were also seemingly normal with respect to vitamin content so far as the requirements were known.

These rations were fed to the same cows continuously over a period of several years. The cows on the high protein ration consumed far more protein, often several times as much, as called for by the most liberal standards, certainly much more than would be found in any reasonable combination of the common dairy feeds. Milk production was quite good but probably somewhat less than would have been obtained on the usual type of good ration. The cows lost weight only at calving time, remained in a high state of flesh at all times and the calves produced appeared well developed and thrifty. Breeding however often seemed to be delayed leading to longer lactation periods and longer intervals between calvings than is usually desired. Sterility was the final result in many cases.

Though the cows on the low protein feeding received all they would take of the prescribed ration they were clearly on a protein deficient basis most of the time. The protein supplied was used with a remarkable degree of efficiency. Milk production was much less, probably about half what it would have been on an ordinary good ration. The cows were usually in a fair condition of flesh at calving time and the calves apparently normal and of good birth weight. Besides the customary loss of live weight at calving these cows continued to lose weight through the period of heavy production until about the fifth month. At this time their condition is probably best described by the word "emaciated", though they remained active and seemingly in good health. They then gained weight and condition slowly at first through the remainder of the lactation and dry period.

Delayed breeding and sterility also occurred to some extent in this group though less frequently than in the high protein group. The presence of Brucellosis in the herd at that time makes difficult a correct appraisal of the effect of the respective rations in this regard.

A study of the composition of the milk produced on these widely divergent rations rather early in the course of this type of feeding has been previously presented (23). Later the writer developed a more suitable method for the determinations of ammonia and urea in milk than were available at the time of that report (25). It was also discovered that the higher values for amino nitrogen reported there in the case of the high protein cows probably resulted from the decomposition of urea during the concentration of the samples as called for in the method.

Another method also developed for the determination of amino acids in blood was then used. This gave somewhat higher values for amino acids with little difference in the values obtained for the two groups of cows as shown in Table 11. This leaves urea N and the total

TABLE 11.—Nitrogen Partition in Milk, Milligrams per 100 cc. of Milk in Different Forms

Fraction	Low Protein Feeding		High Protein Feeding	
	Range	Mean	Range	Mean
Total N	393 –701	508	416 –598	499
Casein N	292 –483	397	275 –419	352
Albumin N	64 –137	97	72 –163	104
Residual non-prot. N	8 – 30	14	28 – 46	43
Ammonia N	0.27– 0.60	0.42	0.23– 0.55	0.41
Amino acid N	1.9 – 4.3	2.83	2.06– 4.30	3.07
Urea N	2.0 – 5.0	3.4	20 – 25	22.7
Uric acid N	0.07– 2.4	0.86	0.04– 2.20	0.84
Creatine and creatinine N	0.89– 1.65	1.34	0.90– 1.97	1.47

non protein nitrogen, mostly because it includes the urea, as the most striking variants in the composition of the milk between these groups of cows. As reported in the previous study, however, the albumin precipitated by tannic acid in the fiftrate from the acetic acid precipitation of casein was somewhat higher and the casein somewhat lower in the milk from the high protein feeding. The individual figures vary due to the inclusion of additional analyses but the general trend of the results remains the same as previously reported.

SUMMARY

With such relatively normal performance of the cows in this experiment on the long continued use of rations far more extreme in both directions than would ever be likely to be supplied in practice, it would seem that there need be little concern about permanent damaging effects to the cow from the use of too much or too little protein in the ration; so long as the common dairy feeds of good quality are supplied in reasonable variety and amount.

One-third to one-half as much protein as supplied in our high protein ration would have been ample and probably would have given better results. Clearly such an excess of protein is no stimulant to high production.

Certainly also the need for much more protein than was supplied in the low protein ration, probably two or three times as much, has been forcefully demonstrated.

There has also been shown, however, a surprising degree of adaptability on the part of the dairy cow toward the long continued use of rations abnormal with respect to protein content.

Our conclusion announced earlier that urea was the major variant in the milk produced by the groups of cows is confirmed by the present work.

Feeding experiments conducted by others in this department on the milk from these cows showed no detectable difference in the feeding value for rats or calves between the milk produced by the respective groups of cows.

Although breeding was often delayed, calves of normal weight and appearance were produced by the cows on both types of ration.

REFERENCES

1. Addis, T., McKay, E. M., and McKay, L. L. The Effect of the Long Continued Administration of Diets Containing an Excess of Certain Food Elements. I. Excess of Protein and Cystine. J. Biol. Chem., 71: 139. 1926.

2. Armsby, H. P. The Nutrition of Farm Animals. The MacMillan Co., New York. 1917.

3. Becker, R. B., Neal, W. M., and Shealy, A. L. Effect of Calcium Deficient Roughages Upon Milk Yield and Bone Strength in Cattle. J. Dairy Sci., 17: 1. 1934.

4. Blatherwick, N. R and Medlar, E. M. Chronic Nephritis in Rats Fed High Protein Diets. Arch. Int. Med., 59: 572. 1937.

5. Buschman, A. and Associates. Untersuchungen über den Eiweissreicher bedarf der Milchkuh und den Einfluss eiweissreicher und eiweiss armer Fütterung auf die Menge und Zusammensetzung der Milch. Landw. Vers Stat. Vol. CI Heft 1-1V. 1923.

6. Cary, C. A. Milk and Butterfat Production on High and Low Protein Rations. J. Dairy Sci., 18: 445. 1935.

7. Eckles, C. H. Digestion Trials with Two Jersey Cows on Full Ration and on Maintenance. Missouri Agr. Expt. Sta. Bull. 4. 1911.

8. Ellenberger, H. B., Newlander, J. A., and Jones, C. H. Calcium and Phosphorus Requirements of Dairy Cows. II. Weekly Balances Through Lactation and Gestation Periods. Vermont Agr. Expt. Sta. Bull. 342. 1932.

9. Ellet, W. B. and Haldaway, C. W. The Effect of High Protein and High Energy Rations in Feeding Dairy Cows. Virginia Agr. Expt. Sta. Tech. Bulls. 12 and 20. 1920.

10. Evans, N. and Risley, E. H. Protein as a Cause of Nephritis. J. Am. Med. Assn., 84: 1870. 1925.

11. Henry, W. A. and Morrison, F. B. Feeds and Feeding. The-Henry-Morrison Co., Madison, Wisconsin. 16th Ed. 1916.

12. Hills, J. L. The Maintenance Requirement of Dairy Cattle. Univ. of Vermont Agr. Expt. Sta. Bull. 226. 1922.

13. Hills, J. L., Beach, C. L., Borland, A. H., Washburn, R. M., Story, G. F. E., and Jones, C. H. Protein Requirement of Dairy Cows. Univ. Vermont Agr. Expt. Sta. Bull. 225. 1922.

14. Huffman, C. F., Robinson, C. S., and Winter, O. B. The Calcium and Phosphorus Metabolism of Heavily Milking Cows. J. Dairy Sci., 13: 432. 1930

15. Morris, S. and Wright, N. C. The Nutritive Value of Protein for Milk Production. J. Dairy Res., 5: 1. 1933.

16. Morrison, F. B. Feeds and Feeding. The Morrison Publishing Co., Ithaca, New York. 21st Ed. 1948.

17. Osborn, T. B., Mendell, L. B., Park, E. A., and Winternitz, M. C. Physiological Effects of Diets Unusually Rich in Protein or Inorganic Salts. J. Biol. Chem., 71: 317. 1926-27.

18. Putney, F. S. and Armsby, H. P. Computation of Dairy Rations. Pennsylvania Agr. Expt. Sta. Bull. 143. 1916.

19. Perkins, A. E. and Monroe, C. F. The Effect of High and Low Protein Content on the Digestibility and Metabolism of Dairy Rations. Ohio Agr. Expt. Sta. Bull. 376. 1924.

20. Perkins, A. E. Protein Requirement of Dairy Cows. Ohio Agr. Expt. Sta. Bull. 389. 1925.

21. Perkins, A. E. and Monroe, C. F. The Apparent Digestibility of Low Protein Rations by Dairy Cows. J. Dairy Sci., 8: 405. 1925.

22. Perkins, A. E. Fat Protein Relationship in Normal Milk. Ohio Agr. Expt. Sta. Special Circular 29. 1930.

23. Perkins, A. E., Krauss, W. E., and Hayden, C. C. The Chemical Composition and Nutritive Properties of Milk as Affected by the Level o fProtein Feeding. Ohio Agr. Expt. Sta. Bull. 515. 1932.

24. Perkins, A. E. and Monroe, C. F. Dietary Acidosis in Dairy Cattle. J. Dairy Sci., 16: 413. 1933.

25. Perkins, A. E. Determination of Ammonia and Urea in Milk. J. Ind. and Eng. Chem. Anal. Ed. 10: 69. 1938.

26. Polvogt, L. M., McCollum, E. V., and Simmonds, N. Production of Kidney Lesions in Rats by Diets Defective Only in that they Contained Excessive Amounts of Protein. Johns Hopkins Hosp. Bull. 34: 168. 1923.

27. Ragsdale, A. C. and McIntyre, C. W. Univ. of Missouri Agr. Expt. Sta. Bull. 444. Ann. Rept., 1939.

28. Steiner, W. Untersuchung über die Konservierung von Güinfutter Nach der Verfahrung Von A 2. Virtanen Landw. Vers. Sta., 124: 1. 1935.

29. Watson, S. J. and Ferguson, W. S. The Value of Artificially Dried Grass Silage Made with Added Molasses and A.I.V. Fodder in the Diet of the Dairy Cow and Their Effect on the Quality of the Milk. J. Agl. Sci., 26: 337. 1936.